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A review paper on Vapour deposition coating

Vishakha S. Pahade, Pankaj S. Chavan, Vaishali P. Baisane

Abstract— **with the demands of lower cost, higher accuracy, better surface finish, and shorter process time in the precision engineering industry, high-speed machining of high hardness materials including hardened tool steels has become increasingly important. To improve the performance and to extend the life of the cutting tools, various types of vapour deposition coatings have been developed. Vapour deposition coatings for high-speed machining consist of multiple layers because of the requirements for high-adhesion strength to the substrate, high-thermal stability, high hardness, a low-friction coefficient, and good compatibility. The present techniques used to produce these coatings include physical-vapour deposition (PVD), and chemical vapour deposition (CVD).Traditionally used coatings like TiN, CrN, and their alloyed nitride coatings, have high hardness and good adhesion strength on common materials used in the tooling industry. However, these coatings have poor performance in high-speed machining applications, especially in the cutting of hardened tool steels, because of phase transition (oxidation) at high temperature. This research work gives the introduction about PVD and CVD.**

Index Terms—Coating, PVD, CVD.

1. Introduction

Though many developments in the cutting tool materials and surface treatments are carried out, not a single material have a fruitful combination of all those properties required by a machining process. In order to have longer tool lives and increase in productivity, one must go for surface engineering on tools. The harder materials lack in toughness and also they are sensitive to vibration and chatter. The refractory materials possess excellent wear resistant material on a tougher substrate. The coatings are extremely fined grained and dense with a high degree of purity. As the coatings are diffused into the underlying metal, the bond is perfect. The coating becomes a part of the tool. Low thermal conductivity properties also eliminate cold welding and chip building-up.
In this context, appropriate selection of cutting geometry and tool material is crucial to be competitive, especially in the field of difficult-to-machine materials, such as stainless steels. Selection of tool coating plays a fundamental role as far as improvement of cutting tool performance is affected directly. As result, in the last years a significant amount of studies has focused in improving coatings with respect to performance, hardness, thermal resistance and low friction coefficients [1]. Thin film coatings are being increasingly used for tribological applications. In modern industrial system the major challenges are to design and produce materials having a low wear rate and low coefficient of friction for a wide range of working environments. Surface engineering is a fast growing area of research because of the high industrial demands for friction control and wear resistance, coupled with enabling technology that produces new coatings with desirable tribological performance as well as mechanical properties. These coatings have many tribological applications such as gas turbine bearings, diesel engine piston rings, aerospace components or forming tools, etc. The elevated friction and wears generated causes essential energetic and material losses and decreases efficiency of mechanical systems [3].

The application of coatings to improve tribological properties of tools (e.g. for metal cutting and forming) and machine elements (e.g. sliding bearings, valves) is constantly increasing. During the last decade the number of coating materials, structures, combinations and applications has increased exponentially. We could not imagine high speed machining, hard machining and dry machining without appropriate hard protective coatings.

Vishakha S. Pahade, Mechanical Department, Dr. BAMU/PES, Aurangabad, INDIA, (e-mail: vishakhap360@gmail.com).
Pankaj S. Chavan, Mechanical Department, Dr. BAMU/DIEMS, Aurangabad, INDIA, (e-mail: pnkjchavan@gmail.com).
Vaishali P. Baisane, Mechanical Department, Dr. BAMU/PESCOE, Aurangabad, INDIA, (e-mail: vaishalibaisane06@gmail.com).

2. COATING

A coating is a covering that is applied to the surface of an object, usually referred to as the substrate. There are different types of coating such as Chemical coating, Electrochemical coating, Thermo chemical coating, Thermo coating, vapour deposition coating & Mechanical coating.

2.1VAPOUR DEPOSITION COATING

It is a family of processes used to deposit layers of material atom by atom or molecule by molecule on a solid surface. This process is operates at below atmospheric pressure.

2.2 TYPES OF VAPOUR DEPOSITION COATING

a. Physical vapour deposition: In this process the material that is introduced onto the substrate is introduced in solid form.

b. Chemical vapour deposition: In this process the material that is introduced onto the substrate is introduced in a gaseous form.

a. PHYSICAL VAPOUR DEPOSITION

Physical vapour deposition is fundamentally a vaporization coating technique, involving transfer of material on an atomic level. It is an alternative process to electroplating. The process is similar to CVD except that the raw material .i.e. The material that is going to be deposited starts out in solid form, whereas in CVD , the precursor are introduced to the reaction chamber in the gaseous state. This process involves several steps. The whole process is done under vacuum conditions. First, the solid precursor material is bombarded with a beam of electrons, so that it will give atoms of that material. These atoms are then transported into the reacting chamber where the coating substrate is placed. While transporting, atoms can react with other gases to produce a coating material or the atoms themselves can be the coating material. Then they deposit on the substrate making a thin coat. PVD coating is used to reduce friction or to improve oxidation resistance of a substance or to improve the hardness, etc.

Hard coatings if applied by physical vapour deposition (PVD) are principally known to have the ability to reduce tool wear of high speed steel (HSS) and carbide metal cutting tools [2]. The purpose of the physical vapour deposition (PVD) process is to protect the surface steel from corrosion and wear and then decrease their reactivity with the external medium. Availability of tools with sharp cutting edges is essential in light turning of small parts; so that, smooth operation is favoured with minimal cutting forces avoiding part deformations and, consequently, dimensional errors. In this case, PVD process is optimum for obtaining sharp edges since coating layers can be applied with few microns thickness over a resistant substrate, which helps to maintain the edge integrity.

The process involved four steps:

1. Evaporation
2. Transportation
3. Reaction
4. Deposition

Evaporation:

During this stage, a target, consisting of the material to be is bombarded by a high energy source such as a beam of electrons or ions. This dislodges atoms from the surface of the target vaporizing them.

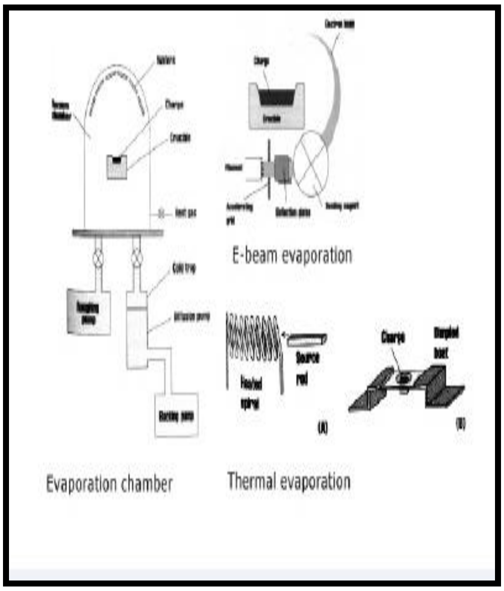

Figure 1. Evaporation process.

Transportation:

This process simply consists of the movement of vaporized atoms from the target to the substrate to be coated and will generally be a straight line affair.

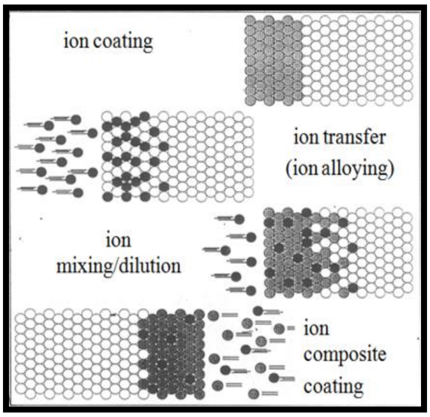

Figure 2. Transportation process.

Reaction:

In some cases coatings will consist of metal oxides, nitrides, carbides and other such materials. In these cases, the target will consist of the metal. The atoms of metal will then react with the appropriate gas during the transport stage.

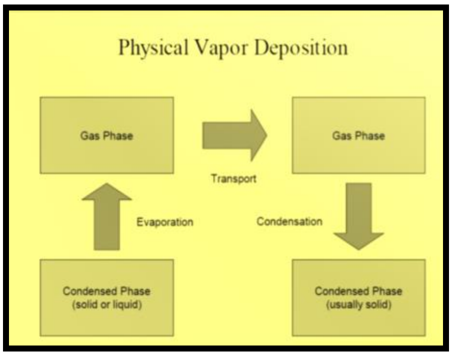

Figure 3. Reaction process.

Deposition:

This is the process of coating build up on the substrate surface. Depending on the actual process, some reactions between target materials and the reactive gases may also take place at the substrate surface simultaneously with the deposition process. The component that is to be coated is placed in a vacuum chamber. The coating material is evaporated by intense heat from, for example, a tungsten filament. An alternative method is to evaporate the coating material by a complex ion bombardment technique. The coating is then formed by atoms of the coating material being deposited onto the surface of the component being treated.

b. CHEMICAL VAPOUR DEPOSITION

CVD is a method to deposit solid and form a thin film from gaseous phase material. This method is somewhat similar to PVD. In CVD the material is coated on a substrate material. It is the process of diffusive convective transport of depositing species to a substrate with many intermolecular collisions driven by a concentration gradient. To do this coating, the coating material is sent to a reaction chamber in the form of vapour having a certain temperature. Then at a reaction chamber, the gas reacts with the substrate, or it is decomposed or deposited on a substrate. So in a CVD apparatus there should be a gas delivery system, reacting chamber, substrate loading mechanism and an energy supplier. Other than this the reaction is carried out in a vacuum to ensure that there are no gases other than the reacting gases. The substrate temperature is critical for determining the deposition. Thus there should be a way to control the temperature and pressure inside the apparatus. Finally, the apparatus should have a way to remove the excess gaseous waste out. The coating material should be volatile, and the same time stable in order to be converted to the gaseous phase and then coat onto the substrate. Hybrids like SiH4, GeH4, NH3, halides, metal carbonyls, metal alkyls, and metal alkoxides are some precursors. Precursor is introduced into a reaction chamber and is controlled by balanced flow regulators and control valves. Precursor molecules pass by the substrate, are drawn into the boundary layer, and are deposited on the surface of the substrate. The reactant gases are introduced into a reaction chamber and are decomposed and reacted at a heated surface to form the thin film.CVD technique is used for coating on semiconductor, composites, Nano machines, optical fibres, catalyst, etc.

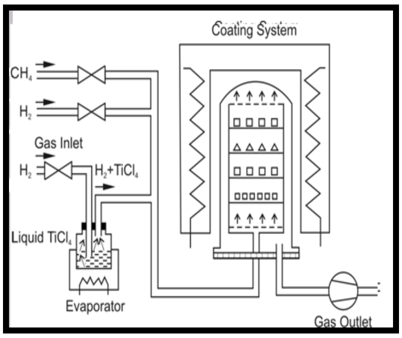

Figure 4. Chemical vapour deposition process.

Table 1: Comparison of PVD and CVD

Sr. No.	PVD	CVD
1	Substrate bending strength does not decrease.	Substrate bending strength decreases.
2	No substrate's deterioration.	Substrate may deteriorate.
3	Good for anti-chipping performance.	Substrate may soften.
4	Coating temp.400 -600 ˚c	Coating temp. 900-1100 ˚c
5	Coating thickness1-3µm.	Coating thickness 6- 9µm.
6	Not Suitable for mass production	Suitable for mass production.

Depending on the application, there are sound arguments for the use of either process (PVD or CVD). One reason to use a physical vapour deposition process (such as sputtering) instead of chemical vapour deposition is the temperature requirement.CVD processes run at much higher temperatures than PVD processes, usually between 300°C and 900°C. This heat is supplied by a furnace, laser, but it always heats the substrate. Substrates that cannot tolerate this temperature must have thin films deposited by the physical form of vapour deposition instead. The benefit of the substrate temperature in some CVD processes is that there is less waste deposition, especially in cold-wall reactors, because only the heated surfaces are coated. With the use of a laser heating system, the chemical vapour deposition process becomes selective to the path of the laser; this is a distinct advantage over physical vapour deposition methods such as sputtering. Molecular beam epitaxy (PVD process) has a distinct advantage of atomic level control of chemical composition, film thickness, and transition sharpness. This process is relatively more expensive, but is worth the added cost for applications that demand higher precision. Sputtering (PVD process) does not require the use of specialized precursor materials as used in CVD. Sputtering has a wider range of materials readily available for deposition. Another advantage of physical vapour deposition over chemical vapour deposition is the safety issue of the materials that are used for chemical vapour deposition. It is known that some precursors and some by-products are toxic, pyrophoric, or corrosive. This can cause issues with material handling and storage. There are applications that could use either deposition method successfully. However, an experienced engineer could easily recommend chemical or physical vapour deposition for a job based on criteria such as cost, film thickness, source material availability, and compositional control.

Some turning applications require specific tools with optimized geometries and coatings. For example, availability of tools with sharp cutting edges is essential in light turning of small parts; so that, smooth operation is favoured with minimal cutting forces avoiding part deformations and, consequently, dimensional errors. In this case, PVD process is optimum for obtaining sharp edges since coating layers can be applied with few microns thickness over a resistant substrate, which helps to maintain the edge integrity. On the contrary, CVD coatings are featured by rounded edges due to the higher thickness of layers (around 10 m), what make them inadequate for light turning. Besides, thickness, thermal properties, residual stresses and grades of adhesion are very different between CVD and PVD coatings. On one hand, PVD coatings provide resistance to wear due to their high hardness. PVD coatings are characterized by compressive stresses which provide tenacity to the edge and improve tool reliability. PVD coatings are recommended when toughness and sharp edge is required simultaneously. Also, these coating are recommended for machining of sticky materials. Moreover, the use of WC with fine grain size (less than a micron) improves even more the strength of PVD coated sharp edges. On the other hand, CVD coatings are characterized by residual traction stresses and fissures caused by heating, mainly due to the great difference between thermal expansions coefficients for CVD coating and hard metal substrate. Consequently, tools with CVD coatings are more susceptible of reaching a rough border than tools with PVD coating.

CONCLUSION

From the above it should be clear that a coating increases the mechanical properties of materials. Both coating and substrate properties must be carefully considered to obtain a good composite material. Surface engineering is one of the most important technologies that may contribute to a sustainable development in the industrial world, through the conservation of earth resources, a reduction of waste, and energy savings. PVD coatings can be considered more reliable and economical than CVD coatings because it provides better mechanical properties i.e wear resistance, hardness, thermal resistance, low coefficient friction and tribological properties.

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Miss. Vishakha S. Pahade
ME - Mechanical
Asst. Professor
PES college of Engineering
Aurangabad, MH, India

Mr. Pankaj S. Chavan.
ME - Mechanical
Asst. Professor
DIEMS, Aurangabad
MH, India

Miss Vaishali. P. Baisane
ME - Manufacturing
Asst. Professor
PES college of Engineering
Aurangabad, MH, India